Final Report

DFG Contract No. P0170015
to the
Foundation of California State University Monterey Bay
Project No. A025006901

June 15, 2004

Hydrographic Data Acquisition In Support Of MLPA And MLMA Implementation

Prepared by
Rikk Kvitek, Pat Iampietro, Carrie Bretz, Kate Thomas,
Saori Zurita, Bryan Jones, Erica Morris

Seafloor Mapping Lab
California State University, Monterey Bay
100 Campus Center
Seaside, CA 93955

http://seafloor.csumb.edu
Final Report

DFG Contract No. P0170015
to the
Foundation of California State University Monterey Bay
Project No. A025006901

June 10, 2004

Hydrographic Data Acquisition In Support Of MLPA And MLMA Implementation

Prepared by
Rikk Kvitek, Pat Iampietro, Carrie Bretz, Kate Thomas,
Saori Zurita, Bryan Jones, Erica Morris

Seafloor Mapping Lab
California State University, Monterey Bay
100 Campus Center
Seaside, CA 93955

http://seafloor.csumb.edu
PROJECT SUMMARY

The goal of this three-year contract has been to produce high-resolution marine habitat maps of nearshore sites deemed critical to the implementation of the Marine Life Protection Act (MLPA) and Marine Life Management Act (MLMA) by the California Department of Fish and Game (DFG) Marine Region management team. As part of this contract, the CSUMB Seafloor Mapping Lab (SFML) ran 2755 km of hydrographic survey lines, mapping a total of 243 km$^2$ of habitat in southern and central California. The maps include three of the MPAs and their associated controls within the new Channel Island Marine Reserve Network, as well as nearshore data gaps from the Monterey Peninsula to Point Sur.

Note: The boundaries shown in this report for the Channel Island MPAs and their respective controls are for the priority MPA mapping areas as specified by DFG, and extend to the 3-mile state waters limit. The true offshore boundaries of the Channel Island Marine Reserves in most cases do not extend to the 3-mile limit. All habitat analyses and calculations for the Channel Island MPA’s presented in this report refer to and are based on the MPA and control survey areas prescribed by DFG, and extend out to the 3 mile limit or maximum depth range of the instrumentation.

Table 1. Total survey track lines run and habitat area mapped in central and southern California.

<table>
<thead>
<tr>
<th>Areas Surveyed</th>
<th>Depth Range (m)</th>
<th>Survey Track</th>
<th>Area Mapped</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location</td>
<td>Site</td>
<td>Minimum</td>
</tr>
<tr>
<td>Channel Islands</td>
<td>Gull Island</td>
<td>4</td>
<td>261</td>
</tr>
<tr>
<td></td>
<td>Carrington Pt</td>
<td>3</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>South Point</td>
<td>7</td>
<td>252</td>
</tr>
<tr>
<td>Central Coast</td>
<td>Monterey Peninsula</td>
<td>6</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>Yankee Pt.</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Soberanes Pt.</td>
<td>7</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>Kasler's Pt</td>
<td>8</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Hurricane Pt.</td>
<td>5</td>
<td>56</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>2755</td>
</tr>
</tbody>
</table>

Because DFG redirected the focus of this contract to the Channel Islands in late 2002, greatly increasing the original geographic scope of work, the products from the mapping surveys are limited to those derived from multibeam bathymetry and sidescan sonar (where appropriate). The products from the entire mapping effort are being provided as GIS layer content to DFG as part of this report in DVD format. Because the contract was terminated a month early by DFG, final cleaning of the central California bathymetry grid data from Yankee Point to Point Sur is being completed with support from the Monterey Bay National Marine Sanctuary SIMoN Project, and will be provided to DFG by August 2004. Products delivered with this report include:

Channel Islands MPA’s
- Multibeam bathymetry
  - Shaded relief geotiffs – gray scale
  - Shaded relief geotiffs – colored by depth contours
  - Bathymetry DEM grids
  - Slope analysis grids
• Rugosity analysis grids
• Habitat classification (rock versus sediment) grids
• Bathymetric contour line shapefiles
• Statistical comparison of habitat distributions in the 3 MPA’s versus their control sites
• Sidescan sonar mosaics (where depth ranges are appropriate)
• Xyz bathymetry asc files
• Xyz bathymetry shapefiles
• Base map data (MPA boundaries, coastlines, nautical charts)
• Full FGDC metadata

Central Coast (All of Monterey Peninsula to Pt Sur)
  Multibeam bathymetry
    • Shaded relief geotiffs – gray scale
    • Shaded relief geotiffs – colored by depth contours
    • Full FGDC metadata

Report and data on the identification of seafloor squid egg distribution in the sidescan sonar records.
Report on GIS habitat analysis of the Del Monte shale beds relating rockfish distribution to habitat models derived from multibeam bathymetry. (GIS data available upon request.)

SIGNIFICANT FINDINGS

HABITAT IN CHANNEL ISLANDS MARINE RESERVES COMPARED TO THEIR CONTROLS
Two of the Channel Island MPA sites, Carrington Point and South Point on Santa Rosa Island, had no significant difference between the distributions of habitat types (rock versus sediment) within the MPAs versus their paired control sites. Gull Island, the Santa Cruz Island MPA, however, did contain significantly more rocky habitat than its paired control site, both in total and when stratified by depth according to the habitat preferences of keys species of concern.

PREDICTING ROCKFISH DISTRIBUTION FROM MULTIBEAM BATHYMETRY DATA
The central coast habitat data was applied to two fisheries related issues during the course of the project. At the Del Monte shale beds, multibeam-derived products (rugosity, slope, topographic position index and depth) were used to create GIS spatial data models that successfully predicted the distribution of 8 species of rockfish (example shown in Fig. 20). The results from this work are presented as a separate report in the appendix. The numerous GIS analysis files are available upon request from SFML.

SIDESCAN SONAR MAPPING ACCURATELY IDENTIFIES SQUID EGG MASSES ON SEAFLOOR
During the spring 2004 habitat mapping surveys, SFML staff and colleagues from the Woods Hole Marine Biological Laboratory used sidescan and multibeam sonar to identify and map the distribution and abundance of squid egg masses and associated habitat geomorphology. Squid egg clusters < 1m in diameter as well as dense aggregations can be easily discerned in the sidescan imagery and were verified using georeferenced ROV video surveys. These results demonstrate that acoustic remote sensing can be used to identify essential spawning habitat critical for squid recruitment, as well as monitoring seasonal reproductive output as a means of regulating the squid fishery.
TABLE OF CONTENTS

PROJECT SUMMARY ................................................................. 2
 Significant findings ................................................................. 3
   Habitat in Channel Islands Marine Reserves compared to their controls ....... 3
   Predicting rockfish distribution from multibeam bathymetry data............... 3
   Sidescan sonar mapping accurately identifies squid egg masses on seafloor ... 3

LIST OF CONTENTS ........................................................................ 4
LIST OF TABLES ............................................................................. 5
LIST OF FIGURES ........................................................................... 5

PURPOSE .......................................................................................... 8

PROJECT DESCRIPTIONS ................................................................ 9
  Multibeam Sonar Data Collection ..................................................... 9
  Central California Habitat Mapping ............................................... 9
    Essential Fisheries Habitat Delineation using multibeam and sidescan data .... 29
      Predicting rockfish distribution from multibeam bathymetry data .......... 29
      Sidescan sonar mapping identifies squid egg masses on Monterey Bay seafloor 30
  Southern California Habitat Mapping – Channel Islands Marine Reserve Network .... 31
    Background ............................................................................ 31
    The Channel Islands MPA Network .......................................... 31
    Species of concern ................................................................ 34
    Project Objective and Goals .................................................... 35
    Data acquisition ...................................................................... 36
    Data Analysis for Rocky Habitat .......................................... 52
    Results ................................................................................. 54
    Gull Island MPA and control ...................................................... 54
    Carrington Point MPA and control ............................................ 54
    South Point MPA and control ....................................................... 55
    Conclusions ............................................................................ 57
    Literature cited ...................................................................... 58

GIS DATA INDEX .......................................................................... 60
  Dataset Overview ..................................................................... 60
  Geographic Extent ..................................................................... 60
  Projection & Coordinate System .................................................. 60
  General Description of Data Layers .......................................... 60
  GIS Data & Project Organization .............................................. 63
  Metadata .................................................................................. 63
  Data Accuracy .......................................................................... 63

APPENDIX - PREDICTING ROCKFISH DISTRIBUTIONS USING GIS AND MULTIBEAM BATHYMETRY DATA ........................................... 1
LIST OF TABLES
Table 1. Total survey track lines run and habitat area mapped in central and southern California. ................................................................. 2
Table 2. Selected species-of-interest from Marine Protected Areas in National Oceanic and Atmospheric Administration’s Channel Island National Marine Sanctuary (Ugoretz 2002) .......................................................... 35
Table 3. Amount of rocky habitat found within each of the MPAs and paired control sites ........................................................................ 55
Table 4. Gull Island habitat distribution by species of concern .................. 56
Table 5. Carrington Point, Santa Rosa Island habitat distribution by species of concern .......................................................... 56
Table 6. South Point, Santa Rosa Island habitat distribution by species of concern .......................................................... 56
Table 7. Data layers: example graphic, layer label as displayed, source file and description of content and source .............................................. 60

LIST OF FIGURES
Figure 1. New multibeam bathymetry data collected to fill data gaps around Monterey Peninsula are shown in red shaded-relief. Previously collected multibeam data collected by SFML for DFG shown in gray. The new data more than doubles the high-resolution coverage .......................................................... 10
Figure 2. New multibeam data coverage for central California, from Yankee Point to Point Sur, shown in gray scale (left) and colored by depth (right) .................................................................... 11
Figure 3. Full multibeam data coverage for the Del Monte shale beds in gray-scale shaded relief ........................................................................ 12
Figure 4. Full multibeam data coverage for Pt. Piños to Cannery Row in gray-scale shaded relief ........................................................................ 13
Figure 5. Full multibeam data coverage for Pt. Piños to Cannery Row in shaded relief colored by depth at 10m intervals ................................................. 14
Figure 6. Full multibeam data coverage for Pt. Piños to Cypress Pt. in shaded relief .......................................................... 15
Figure 7. Full multibeam data coverage for Pt. Piños to Cypress Pt. in shaded relief colored by depth at 10m intervals .......................................................... 16
Figure 8. Full multibeam data coverage for Cypress Pt. to Pt. Lobos in shaded relief .......................................................... 17
Figure 9. Full multibeam data coverage for Cypress Pt. to Pt. Lobos in shaded relief colored by depth at 10m intervals .......................................................... 18
Figure 10. Full multibeam data coverage for Pt. Lobos Peninsula in shaded relief .......................................................... 19
Figure 11. Full multibeam data coverage for Pt. Lobos in shaded relief colored by depth at 10m intervals .......................................................... 20
Figure 12. Full multibeam data coverage for Yankee Pt. to Soberanes Pt. in shaded relief .......................................................... 21
Figure 13. Full multibeam data coverage for Yankee Pt. to Soberanes Pt. in shaded relief colored by depth at 10m intervals .......................................................... 22
Figure 14. Full multibeam data coverage for Soberanes Pt. to Kaslers Pt. in shaded relief .......................................................... 23
Figure 15. Full multibeam data coverage for Soberanes Pt. to Kaslers Pt. in shaded relief colored by depth at 10m intervals .......................................................... 24
Figure 16. Full multibeam data coverage for Kaslers Pt. to Hurricane Pt. in shaded relief .......................................................... 25
Figure 17. Full multibeam data coverage for Kaslers Pt. to Hurricane Pt. in shaded relief colored by depth at 10m intervals. ................................................................. 26
Figure 18. Full multibeam data coverage for Hurricane Pt. to Pt. Sur in shaded relief. ... 27
Figure 19. Full multibeam data coverage for Hurricane Pt. to Pt. Sur in shaded relief colored by depth at 10m intervals. ......................................................... 28
Figure 20. Model 4 – Deep: Distance to Optimal – TPI50 Peaks + Slope + Rugosity + Depth. Displays distribution and abundance of three species in the spring dataset with preference for deeper water: S. serranoides/S. flavidus, S. rosaceus, and S. rubrivinctus. ......................................................................................... 29
Figure 21. Location of squid egg mop concentrations displayed on multibeam bathymetry DEM and sidescan sonar image of squid egg masses found lying along a fault line near Pt. Cabrillo, Monterey Peninsula. .................................................. 30
Figure 22. The Channel Marine Reserve Network consists of twelve MPAs, ten of which are designated as “no-take zones” and two, which allow limited recreational fishing ........................................................................................................ 32
Figure 23. DFG priority mapping sites in CIMPA network given to the SFML. Green areas are the MPAs, unfilled hatched areas are the adjacent control sites for the MPA, and red circles indicate the three top priority sites mapped for this project (Gull Island, Carrington Point, South Point). The thin red line is the three-mile state waters limit......................................................................................... 33
Figure 24. Multibeam bathymetry data in shaded relief for Carrington Pt., Santa Rosa Island. ........................................................................................................... 38
Figure 25. Multibeam bathymetry in shaded relief, colored by depth for Carrington Point, Santa Rosa Island. .................................................................................. 39
Figure 26. Sidescan sonar mosaic for Carrington Pt., Santa Rosa Island. ....................... 40
Figure 27. Slope analysis of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island. ........................................................................................................... 41
Figure 28. Rugosity analysis of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island. .............................................................................................. 42
Figure 29. Rocky habitat map derived from slope and rugosity analyses of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island. ....................... 43
Figure 30. Multibeam bathymetry in shaded relief for Gull Island, Santa Cruz Island. ........................................................................................................... 44
Figure 31. Multibeam bathymetry in shaded relief, colored by depth for Gull Island, Santa Cruz Island. ...................................................................................... 44
Figure 32. Sidescan sonar mosaic for Gull Island, Santa Cruz Island. ......................... 45
Figure 33. Slope analysis of the multibeam bathymetry DEM for Gull Island, Santa Cruz Island. .............................................................................................. 45
Figure 34. Rocky habitat map based on the slope and rugosity analyses of the multibeam bathymetry DEM for Gull Island, Santa Cruz Island. ......................... 46
Figure 35. Multibeam bathymetry in shaded relief, for South Point, Santa Rosa Island. .. 47
Figure 36. Multibeam bathymetry in shaded relief, colored by 10m depth contours for South Point, Santa Rosa Island. ................................................................. 48
Figure 37. Slope analysis of the multibeam bathymetry DEM, for South Point, Santa Rosa Island. .............................................................................................. 49
Figure 38. Rugosity analysis of the multibeam bathymetry DEM, for South Point, Santa Rosa Island. ...................................................................................... 50
Figure 39. Rocky habitat map based on slope and rugosity analysis of the multibeam bathymetry DEM, for South Point, Santa Rosa Island. .......................... 51

Figure 40. Buffers (250 m radius) placed around randomly generated points used to sample and compare the habitats at the Carrington Point MPA and control site. .... 53
PURPOSE

The purpose of this three-year contract has been to produce high-resolution marine habitat maps of nearshore sites deemed critical to the implementation of the Marine Life Protection Act (MLPA) and Marine Life Management Act (MLMA) by the California Department of Fish and Game (DFG) Marine Region management team. The budget for this project also included the required support for needed maintenance and upgrading of the CSUMB Seafloor Mapping Lab’s (SFML) hydrographic mapping system, owned in part by DFG.

The original focus of the project was to concentrate 1/3 of the mapping effort along the central California coast and 2/3 along southern California coastlines as directed by DFG staff based on Department priorities as they developed during the course of the contract. The central California priorities included filling gaps in the existing habitat data around the Monterey Peninsula so as to provide continuous multibeam bathymetry coverage from as close to shore as safe navigation would allow, out to the inner edge of the multibeam data previously collected by the U.S. Geological Survey (USGS) and the Monterey Bay Aquarium Research Institute (MBARI). Much of the peninsula habitat had already been mapped for DFG by SFML as part of a previous contract, but gaps existed between these data sets and the deeper water USGS/MBARI data as well as in shallower areas due to extensive kelp cover during the original surveys in 2000. The central California priorities were also focused on the Big Sur coastline extending south from Point Lobos and filling the gap between the shore and USGS/MBARI data sets.

In late 2002, DFG re-directed the focus of the contract to the Channel Islands (CI), following the creation of the California Channel Islands MPA Network. As a result, three of the CI MPA’s along with their designated control areas were targeted for mapping in June 2003. The goal of the CI mapping was to quantify the distribution and abundance of habitat types within the three MPA’s and to determine if the selected control areas were sufficiently similar to the MPA’s to serve as comparison sites for monitoring MPA performance. Additional support was obtained from The Nature Conservancy, CI National Park and NOAA for this greatly expanded scope of work.

Note: The boundaries shown in this report for the Channel Island MPAs and their respective controls are for the priority MPA mapping areas as specified by DFG, and extend to the 3-mile state waters limit. The true offshore boundaries of the Channel Island Marine Reserves in most cases do not extend to the 3-mile limit. All habitat analyses and calculations for the Channel Island MPA’s presented in this report refer to and are based on the MPA and control survey areas prescribed by DFG, and extend out to the 3-mile limit or maximum depth range of the instrumentation.

Finally, the contract also provided needed support used for upgrading and installing the hydrographic survey system aboard the new SFML research vessel, R/V VenTresca, specifically designed for shallow-water habitat mapping along the outer California coast. Below we describe and illustrate each of the habitat survey and analysis efforts conducted by SFML in central and southern California for DFG.
PROJECT DESCRIPTIONS

MULTIBEAM SONAR DATA COLLECTION
All multibeam bathymetry and sidescan sonar data were collected using the Reson 8101 multibeam sonar system operated for DFG by the SFML in full compliance with NOS and FGDC data standards and protocols. The Reson 8101 with sidescan sonar option was used in conjunction with a Triton-Elics Isis System for data logging and sonar control, along with Delphmap and BathyPro software for real-time sidescan mosaicking and DEM generation. Vessel motion correction and positioning were performed using an Applanix POS/MV with DGPS corrections provided by a Trimble Navigation ProBeacon receiver (pitch, roll and heading accuracy ± 0.02°, heave accuracy ± 5% or 5cm, horizontal accuracy ±2m). Survey planning and navigation was done with Hypack Max from Coastal Oceanographics. NOAA predicted tidal height values from Tides and Currents software were used for tidal correction of the multibeam data. Sound velocity profile data were collected with an Applied Microsystems SVPlus sound velocimeter.

The survey results were post-processed in CARIS and Isis Sonar, to create final products including geotiffs and grids of the multibeam bathymetry and sidescan sonar imagery. Geomorphological habitat analyses were also performed on the multibeam data to quantify the distribution and abundance of rocky habitat within the survey areas (CI and Monterey Peninsula shalebeds only).

CENTRAL CALIFORNIA HABITAT MAPPING
During 2003 and 2004, the SFML completed filling data gaps in the existing multibeam bathymetry coverage from Monterey Peninsula to Pt Sur. Gaps existed between the USGS/MBARI coverage and that previously completed by the SFML in 2000-01, as well as gaps due to heavy kelp cover during the previous SFML surveys. The new data coverage collected in gaps around the Monterey Peninsula is shown in red in Figure 1, and along the Big Sur coast in Figure 2. These central coast surveys were conducted aboard the R/V MacGinite (2003) and R/V VenTresca (2004) using the Reson 8101 operated for DFG by the SFML.
Figure 1. New multibeam bathymetry data collected to fill data gaps around Monterey Peninsula are shown in red shaded-relief. Previously collected multibeam data collected by SFML for DFG shown in gray. The new data more than doubles the high-resolution coverage.
Figure 2. New multibeam data coverage for central California, from Yankee Point to Point Sur, shown in gray scale (left) and colored by depth (right).

Detailed charts of each of the central coast survey areas from the Del Monte shale beds on the north side of the Monterey Peninsula to Point Sur are present in the following figures. The shaded relief geotiff files used to create these layouts are included on the DVD data disks associated with this report. Because DFG ended the contract with CSUMB a month early, the final grid and xyz files as well as the sidescan sonar mosaics for the central coast survey data will be prepared after the final stages of cleaning have been completed. This step is being funded through support from the Monterey Bay National Marine Sanctuary SIMoN Project, and final products will be completed in August 2004.
Figure 3. Full multibeam data coverage for the Del Monte shale beds in gray-scale shaded relief.
Figure 4. Full multibeam data coverage for Pt. Piños to Cannery Row in gray-scale shaded relief.
Figure 5. Full multibeam data coverage for Pt. Piños to Cannery Row in shaded relief colored by depth at 10m intervals.
Figure 6. Full multibeam data coverage for Pt. Piños to Cypress Pt. in shaded relief.
Figure 7. Full multibeam data coverage for Pt. Piños to Cypress Pt. in shaded relief colored by depth at 10m intervals.
Figure 8. Full multibeam data coverage for Cypress Pt. to Pt. Lobos in shaded relief.
Figure 9. Full multibeam data coverage for Cypress Pt. to Pt. Lobos in shaded relief colored by depth at 10m intervals.
Figure 10. Full multibeam data coverage for Pt. Lobos Peninsula in shaded relief.
Figure 11. Full multibeam data coverage for Pt. Lobos in shaded relief colored by depth at 10m intervals.
Figure 12. Full multibeam data coverage for Yankee Pt. to Soberanes Pt. in shaded relief.
Figure 13. Full multibeam data coverage for Yankee Pt. to Soberanes Pt. in shaded relief colored by depth at 10m intervals.
Figure 14. Full multibeam data coverage for Soberanes Pt. to Kaslers Pt. in shaded relief.
Figure 15. Full multibeam data coverage for Soberanes Pt. to Kaslers Pt. in shaded relief colored by depth at 10m intervals.
Figure 16. Full multibeam data coverage for Kaslers Pt. to Hurricane Pt. in shaded relief.
Figure 17. Full multibeam data coverage for Kaslers Pt. to Hurricane Pt. in shaded relief colored by depth at 10m intervals.
Hurricane Point, Big Sur, California

Figure 18. Full multibeam data coverage for Hurricane Pt. to Pt. Sur in shaded relief.
Figure 19. Full multibeam data coverage for Hurricane Pt. to Pt. Sur in shaded relief colored by depth at 10m intervals.
Essential Fisheries Habitat Delineation Using Multibeam and Side-scan Data

Predicting rockfish distribution from multibeam bathymetry data

The central coast habitat data was applied to two fisheries related issues during the course of the project. At the Del Monte shale beds, multibeam-derived products (rugosity, slope, topographic position index and depth) were used to create GIS spatial data models that successfully predicted the distribution of 8 species of rockfish (example shown in Fig. 20). The results from this work are presented as a separate report in the appendix. The numerous GIS analysis files are available upon request from the SFML.

Figure 20. Model 4 – Deep: Distance to Optimal – TPI50 Peaks + Slope + Rugosity + Depth. Displays distribution and abundance of three species in the spring dataset with preference for deeper water: S. serranoides/S. flavidus, S. rosaceus, and S. rubrivinctus.
Sidescan sonar mapping identifies squid egg masses on Monterey Bay seafloor

During the spring 2004 habitat mapping surveys, SFML staff and colleagues from the Woods Hole Marine Biological Laboratory used sidescan and multibeam sonar to identify and map the distribution and abundance of squid egg masses and associated habitat geomorphology. Squid egg “mops” < 1m in diameter as well as dense aggregations can be easily discerned in the sidescan imagery and were verified using georeferenced ROV video surveys (Fig. 21). These results demonstrate that acoustic remote sensing could be of immense value in the management of the California squid fishery, because this technology can be used to identify essential fisheries habitat critical for squid recruitment, as well as monitoring seasonal reproductive output as a means of regulating the squid fishery. The sidescan sonar imagery from the squid egg habitat mapping is included on the GIS DVD.

Figure 21. Location of squid egg mop concentrations displayed on multibeam bathymetry DEM and sidescan sonar image of squid egg masses found lying along a fault line near Pt. Cabrillo, Monterey Peninsula.
SOUTHERN CALIFORNIA HABITAT MAPPING – CHANNEL ISLANDS MARINE RESERVE NETWORK

In late 2002, DFG redirected the contract to focus our mapping effort to the Channel Islands, following the creation of the California Channel Islands MPA Network (CIMPA). Our Channel Islands mapping goal has been to target DFG’s three highest priority sites and corresponding control areas within the CIMPA as described in the following report.

BACKGROUND

Dramatic declines in fisheries and marine environmental quality, combined with increased human demands for marine ecosystem goods and services, have lead to recent state and federal legislation mandating resource agencies move away from problematic, myopic single-species management (Lubchenco 2003, Grantham 2003) and widen the scope of protection by adopting more integrated, ecosystem-based approaches to the sustainable management of marine resources (Pauly et al. 1998, Gislason et al. 2000, Weber and Henneman 2000, NRC 2001, Roberts 2003). Marine Protected Areas (MPAs) are now being widely promoted as an approach to conserving marine resources while balancing the competing needs of multiple users and stakeholders (Lauck et al. 1998, Hyrenbach et al, 2000, Lindholm 2001, NRC 2001). An increasing body of marine reserve theory indicates that networks of protected sites will offer the most practical and effective approach to MPA design and performance (Murray et al. 1999, NRC 2001, Sala et al. 2002). The Ocean Studies Board report on MPA’s states that the performance of marine reserves should be evaluated through regular monitoring to measure progress toward management goals, thereby facilitating effective adaptive management as well as the scientific advancement of MPA theory and design (NRC 2001). The design and implementation of efficient and effective monitoring however, requires accurate baseline information on the distribution and abundance of habitats within the defined MPA. Baseline knowledge on the extent of MPA habitat and its relationships to regional marine communities would provide needed information for fisheries managers who work not only to design effective monitoring programs, but who must also justify placement of MPAs. If MPAs are to be successful in protecting biological resources from human activities it is necessary to evaluate the extent and health of habitat as well as biodiversity within and adjacent to the reserves.

THE CHANNEL ISLANDS MPA NETWORK

In October 2002, DFG in collaboration with the Channel Islands National Marine Sanctuary (CINMS) and the Fish and Game Commission created the largest network of marine reserves off the west coast within the northern Channel Islands. The Channel Island MPA network encompasses 465km2 within the Channel Islands National Marine Sanctuary, and marks the nation's third largest marine reserve, following the Hawaiian Islands Humpback Whale National Marine Sanctuary and the Florida Keys National Marine Sanctuary. Planning for a network of MPAs was initiated in 1998 by a request to the Fish and Game Commission from the Channel Islands Marine Resources Restoration Committee. In response, the California DFG (CDFG) and the CINMS jointly designed and implemented a process for the creation of MPAs in the Channel Islands. After more than 2 years of meetings involving a broad based constituent group, the Commission
adopted the joint DFG/CINMS proposal, and the Channel Islands Marine Protected Area network became a reality. This designation was the result of two pieces of state legislation: 1) the 1998 Marine Life Management Act (MLMA), requiring that the CDFG adopt an ecosystem-based Nearshore Fishery Management Plan, and 2) the 1999 Marine Life Protection Act (MLPA) requiring that DFG develop and adopt a plan for establishing networks of MPAs in California waters to protect habitats and preserve ecosystem integrity (Weber and Heneman 2000). Within the Channel Islands network of marine reserves, 12 individual MPAs exist as either “no-take zones” or have limited access (Fig. 22). In addition, specific areas adjacent to three of the MPAs (Gull Island, Carrington Point, South Point) are open to public access and have been designated as control sites, intended to aid in the evaluation MPA performance (Fig. 23).

Figure 22. The Channel Marine Reserve Network consists of twelve MPAs, ten of which are designated as “no-take zones” and two, which allow limited recreational fishing
Figure 23. DFG priority mapping sites in CIMPA network given to the SFML. Green areas are the MPAs, unfilled hatched areas are the adjacent control sites for the MPA, and red circles indicate the three top priority sites mapped for this project (Gull Island, Carrington Point, South Point). The thin red line is the three-mile state waters limit.

The northern Channel Islands, located off the coast of southern California, signify a seaward extension of the Santa Monica mountain range. Comprised of Anacapa, Santa Cruz, Santa Rosa, and San Miguel islands, the northern Channel Islands encompasses over 1000 km², much of it subtidal. The Islands lie within a geologic expanse known as the Continental Borderland, the offshore region of basins and elevated ridges between Point Conception, California and Punta Banda, Baja California, Mexico (Norris and Webb 1990). The Continental Borderland is theorized to result from continued large-scale overriding of the North American Plate by the Pacific Plate in southern California. This process has forced movement along the San Andreas Fault System and is the primary cause of the Continental Borderland’s wide shelf and laterally shifted blocks (Dailey et al. 1993). Active folding, thrusting, and strike slip faulting in response to the North American and Pacific plate convergence (Pinter et al. 2003) have combined to create a very complex topography of ridges and shelves that extend from the land onto the shallow continental shelf. This complex and diverse geometry forms prime habitats for many marine organisms. Moreover, the Islands have earned a reputation as the “American Galapagos” due to the unique transition zone of cool waters from the northern...
and central coast combining with warmer water from the south. This mixing of water creates an optimal environment for numerous marine species including breeding pinnipeds and cetaceans, invertebrates, fish and giant kelp.

The DFG, CINMS, and the Channel Islands National Park System (CINPS) are now beginning a cooperative effort to design and implement the monitoring program needed to evaluate the performance of the CIMPA network. The CIMPA network was designed to protect representative and unique marine habitats and populations, as well as detect and monitor any anthropogenic impacts on the ecosystem. Effective monitoring requires specific knowledge of the location and extent of ecologically significant habitats and communities. This baseline information is being used for the selection of appropriate control sites outside the CIMPA network. Moreover, most of the distribution and abundance of habitats and communities in the northern Channel Islands have never been mapped previous to this study as cooperating agencies lacked the highly specialized resources needed to conduct the comprehensive exploration and mapping. Without this baseline knowledge, it is impossible to objectively assess if the MPAs actually support species of concern or to design the cost effective, habitat-specific monitoring program required to rigorously evaluate the performance and success of the CIMPA network.

**SPECIES OF CONCERN**

In addition to assessing environmental change within the MPAs, the MPAs were also designed to provide certain levels of protection and enhancement for a variety of marine species whose populations have declined over the past several decades due to increased fishing pressure. In order for MPAs to be ecologically and economically successful, it is essential to define and understand the relationship of the physical habitat with the resident biological communities. The Channel Islands MPA boundaries were assigned without a priori knowledge of the subtidal terrain, therefore putting into question the adequate protection of habitat-specific marine organisms. To address the issue within the scope of this study, a subset of economically important marine species were selected from Marine Protected Areas in National Oceanic and Atmospheric Administration’s Channel Island National Marine Sanctuary (Ugoretz 2002) to allow for a comparison of available preferred habitat (within the defined MPAs) at depths appropriate for each species (Table 1).

The white abalone (*Haliotis sorense*) population has declined by 96% since 1970 and has therefore been recognized by the federal government as needing immediate protection. This species marks the first mollusk in history to be placed on the federal endangered species list. White abalones are sedentary, inhabiting deep-water rocky reefs near sand channels. Surveys in the Channel Islands area estimate density to be around 0.0001 per m^2^ (Davis et al. 1998).

During the 1980’s, olive rockfish (*Sebastes serranoides*) were an important recreational species throughout southern California. They inhabit areas under kelp or among rocks in waters ranging from the surface to around 120m. As a result of overfishing and poor juvenile survival due to changes in oceanographic conditions, this species has declined by about 83% in CPUE between 1980-1996. Although there are no current stock
assessments of olives it is believed that their abundance has greatly declined south of Point Conception (Leet et al. 2001).

Lingcod (*Ophiodon elongatus*) in the Channel Islands are found mostly in the colder water regions of San Miguel and Santa Rosa Islands. They inhabit rocky substrate at depths of 1–100m. During the 1970’s, this fishery nearly tripled as the markets for their liver oil and seafood increased. Recent lingcod stock assessments suggest that their population is seriously depleted. Currently, California populations are believed to be less than 25% of their pre-1970’s level (Leet et al. 2001).

Table 2. Selected species-of-interest from Marine Protected Areas in National Oceanic and Atmospheric Administration’s Channel Island National Marine Sanctuary (Ugoretz 2002)

<table>
<thead>
<tr>
<th>Species of Concern</th>
<th>Common Depth Range</th>
<th>Preferred Habitat</th>
<th>Federal Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Abalone</td>
<td>20 - 60 meters</td>
<td>Rock</td>
<td>Candidate</td>
</tr>
<tr>
<td>(<em>Haliotis sorenseni</em>)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olive Rockfish</td>
<td>3 - 190 meters</td>
<td>Rock</td>
<td>Vulnerable (declining)</td>
</tr>
<tr>
<td>(<em>Sebastes serranoides</em>)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lingcod</td>
<td>0 - 106 meters</td>
<td>Rock</td>
<td>Vulnerable (declining)</td>
</tr>
<tr>
<td>(<em>Ophiodon elongatus</em>)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PROJECT OBJECTIVE AND GOALS**

The objective of this study was to provide the CINMS, DFG, National Oceanographic and Atmospheric Administration (NOAA), and CINPS with valuable high-resolution (3m) and accurate geospatial habitat maps displaying topographic characteristics of seafloor substrate in three of the Channel Islands MPAs and their designated control sites at Gull Island off Santa Cruz Island, and, Carrington Point and South Point near Santa Rosa Island. This information is needed to help fisheries managers within the various agencies begin a successful monitoring program for the MPAs. The CIMPAs are a test case for the MPA network model and verification of their success with an appropriate control site could have regional and national implications for the development and application of MPA theory. The goals of this study were to:

- Provide high-resolution (3m grid) multibeam bathymetry and sonar-derived GIS habitat map products
- Evaluate suitability of seafloor habitat within MPAs for enhancement/protection of ‘species of concern’.
- Quantitatively assess and compare the distribution and abundance of habitat types within the paired MPAs and their designated control areas to determine if they are sufficiently similar to allow valid MPA performance evaluation.
**DATA ACQUISITION**

Survey operations were conducted aboard the National Park Service’s *R/V Pacific Ranger* in June 2003. The SFML survey team consisted of four people operating during daylight hours (0600-1800 hrs). The entire survey included over 370 tracklines providing complete sonar coverage with a 50% overlap. The multibeam swath was 150 degrees, depth range fell between approximately 6 to 261 meters, and survey speed was 8-10 knots. Multibeam bathymetry data was collected using a Reson 8101 multibeam sonar system. Attitude (pitch, roll, yaw, and heave) and position data were generated at 200 Hz by an Applanix Position and Orientation System, Marine Vessel (POS-MV). Attitude accuracy for the POS/MV pitch, roll and yaw measurements averaged +/-0.02°, while heave accuracy was maintained at +/-5% or 5 cm. Sonar, position, and attitude data were logged in XTF format using a Triton Elics Isis data acquisition system running Isis Sonar software. Multibeam data were monitored in real-time using the 8101 Sonar Processor control interface and 2-D and 3-D display windows in the Isis Sonar and DelphMap software.

Survey planning and navigation was performed using Coastal Oceanographics Hypack Max software. Sound velocity profiles were collected throughout the surveys with an Applied Microsystems Limited (AML) SV+. These profiles were used to correct for variations in sound velocity due to salinity and temperature changes in the water column. Tide corrections were based on NOAA predicted tidal models.

Initial multibeam post-processing was done aboard the R/V Pacific Ranger utilizing Caris HIPS (Hydrographic Information Processing System) software. Soundings were corrected for vessel motion using the TSS POS/MV data, sound velocity, and adjusted to MLLW using NOAA predicted tide tables. All data were filtered, merged and cleaned of false data points or “noise” within Caris HIPS. Geotiffs were exported from Caris HIPS Spatial Editor with 3m resolution in sunshaded grayscale and 10 color rainbow imagery with illumination azimuth =315°, elevation =45° and vertical exaggeration = 5X. Soundings were exported from Caris HIPS as decimated x,y,z ASCII text (shoal biased) with 3m, 100m, 300m, and 500m spacing.

The 3m decimated x,y,z ASCII text was imported into Fledermaus Average Gridder to generate a 3m grid. The 3m Fledermaus grid (.asc) was imported into ArcView 8.3 Spatial Analyst to generate a 3m-bathymetry grid with 10m contour lines.

Digital processing and mosaicking of sidescan data was accomplished using the Isis Sonar and Delph Map software packages (Triton Elics International, Watsonville, CA), and TNT Mips GIS software (Microimages, Inc., Lincoln, NE). Individual xtf trackline files were replayed and bottom tracking of the sonar was supervised to aid in proper slant range correction. Line files were snipped to remove portions with poor imagery from the beginning and/or end of the trackline. Tracklines were corrected for slant-range, layback
(4.02m), and lateral offset (0.76m) and the position data for each line was smoothed using a speed filter. Each line was then gridded, georeferenced and exported from Isis Sonar/Delph Map in geotiff format (0.50m pixel size, UTM Zone 11, WGS84). Individual trackline tiff images were imported into TNT Mips GIS software and areas of poor image quality were extracted and removed. Individual tracklines were then overlaid to produce a mosaic image. A mosaic geotiff was exported from TNT Mips at 0.50m resolution.

The following charts for each of the MPAs and their adjacent control sites show the a) geomorphology as illustrated by multibeam bathymetry in shaded relief (gray scale and colored by depth), b) habitat classification results (rock versus sediment based on slope and rugosity analysis – see description of methods used below), and c) sidescan sonar mosaics (only those mosaics showing sufficient detail when reproduced at the scale of this report’s page size are presented below).

Note that the estimation of rocky habitat is highly conservative. Only those areas that met the stringent criteria established for both slope and rugosity analyses were included to insure the most rigorous statistical comparison of habitat distributions within the MPAs and the paired controls. There are many geomorphic features visible in the shaded relief images that may well be rocky habitat, but the definitive classification of these features as rock will require additional inspection and interpretation of the data in conjunction with video ground truthing of the sites using ROV survey techniques. The algorithmic approach we used for classifying rocky versus soft-sediment habitat was configured to minimize the misclassification of artifacts caused by boat motion, thus insuring the most reliable comparison of the MPA with their controls. We strongly urge those intending to use these data for establishing a monitoring program to verify the identity of habitat types with ROVs, divers or drop cameras whenever possible.
Figure 24. Multibeam bathymetry data in shaded relief for Carrington Pt., Santa Rosa Island.
Figure 25. Multibeam bathymetry in shaded relief, colored by depth for Carrington Point, Santa Rosa Island.
Figure 26. Sidescan sonar mosaic for Carrington Pt., Santa Rosa Island.
Figure 27. Slope analysis of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island.
Figure 28. Rugosity analysis of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island.
Figure 29. Rocky habitat map derived from slope and rugosity analyses of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island.
Figure 30. Multibeam bathymetry in shaded relief for Gull Island, Santa Cruz Island.

Figure 31. Multibeam bathymetry in shaded relief, colored by depth for Gull Island, Santa Cruz Island.
Figure 32. Sidescan sonar mosaic for Gull Island, Santa Cruz Island.

Figure 33. Slope analysis of the multibeam bathymetry DEM for Gull Island, Santa Cruz Island.
Figure 34. Rocky habitat map base on the slope and rugosity analyses of the multibeam bathymetry DEM for Gull Island, Santa Cruz Island.
Figure 35. Multibeam bathymetry in shaded relief, for South Point, Santa Rosa Island.
Figure 36. Multibeam bathymetry in shaded relief, colored by 10m depth contours for South Point, Santa Rosa Island.
Figure 37. Slope analysis of the multibeam bathymetry DEM, for South Point, Santa Rosa Island.
Figure 38. Rugosity analysis of the multibeam bathymetry DEM, for South Point, Santa Rosa Island.
Figure 39. Rocky habitat map based on slope and rugosity analysis of the multibeam bathymetry DEM, for South Point, Santa Rosa Island.
**Data Analysis for Rocky Habitat**

Identification of rocky habitat within defined MPAs and control sites of Santa Cruz (Gull Island site) and Santa Rosa (Carrington Point, South Point sites) Islands was performed using a series of geospatial analysis methods. Digital elevation models (DEM) were created using ESRI® ArcMap 8.3 to display differences in habitat texture within each MPA and adjacent control site. (Figs. 24, 30, 35). Colored contour intervals were added to site DEMs to illustrate depth (Figs. 25, 31, 36). Additional parameters of habitat complexity used to aid in the delineation of rocky habitat included rugosity, defined here as an index of substrate complexity or surface roughness, (Figs. 28 and 38) and slope, a measure of change in surface value over distance, expressed in degrees or as a percentage (Figs. 27, 33, 37). Rugosity grids were generated using the ArcView 3.x extension “Surface Areas and Ratios from Elevation Grids” (Jenness 2003). The rugosity (surface area: planar area ratio) analysis grid was reclassified into two categories (“rock” & "non-rock") using a threshold of 1.001 to 1.005 for the break value between the two classes (every cell with a rugosity above the threshold value was classified as "rock"). The threshold value used was site-specific and chosen subjectively after visually examining reclassification results. Because of the confounding effects of artifacts in the bathymetric DEM, the rugosity analysis was subject to misclassification of habitat in some areas; this was especially problematic in areas that were visually clearly identifiable as flat sedimented plains, but where DEM artifacts caused by ship heave inflated the rugosity values and thus resulted in misclassification as rocky habitat. To minimize this problem, a hand-drawn mask was created to exclude these probable non-rock areas from the reclassification of the rugosity results, and the masked areas were then assigned to the non-rock class. This process still resulted in unquantified misclassification errors of both omission & commission, but an attempt was made to minimize these errors and produce a conservative estimate of rocky habitat distribution and abundance. In general, areas of high complexity are likely to provide more optimal habitat cover for rocky reef fish, as well as locations for macroalgae, corals and sessile invertebrates to settle and grow. Rugosity, slope, and depth analysis outputs were integrated to produce a single image demarcating rocky habitat throughout the entire depth range of each site (Figs. 29, 34, 39), as well as the preferred depth range (20 to 60m) of one of the target, representative species, white abalone (Haliotis sorensoni).

Distribution and abundance of rocky habitat within each MPA and control site pair were compared using a two-sample t-test. Random sampling locations were generated within each MPA and control site using the ArcView® 3.x “Generate Randomly-Distributed Points” extension (Lead 2003). Twenty points per site were randomly distributed throughout the entire depth range appropriate for the species-of-interest at Carrington Point, while at South Point only 17 points in the overall depth range and 8 points in the 20-60m white abalone depth range were used, and at Gull Island 20 and 8 points were used, respectively. To avoid overlap of sampling areas and pseudoreplication, points closer than 500 m to their nearest neighbor were rejected, and no points nearer than 250 m from the edge of the site were used to avoid edge effects. Using the Buffer Wizard tool, a 250-meter radius circular buffer was created around each randomly generated point for use as quadrat sampling units (Fig. 40). Zonal statistics were then used to
quantify the total and percent area of rocky habitat within the circular buffer quadrats, and these values were used in t-test comparisons.

Figure 40. Buffers (250 m radius) placed around randomly generated points used to sample and compare the habitats at the Carrington Point MPA and control site.

In addition to the DEMs, side scan sonar (SSS) imagery was used as a ground-truthing measure and was helpful in isolating habitat features (Figs. 26, 32).
RESULTS

GULL ISLAND MPA AND CONTROL

Approximately 48% (26 km$^2$) of the Gull Island MPA was mapped, while 54% (24 km$^2$) of the adjacent control site was surveyed. The mapped area within the Gull Island MPA extended from 4 – 261 m depth (MLLW). Portions (generally along the inshore edge) of both the MPA and control sites could not be mapped due to the presence of *Macrocystis* and other kelp canopies, shallow conditions, emergent rocks, breaking waves, or other factors that precluded safe acquisition of quality data. A large portion of the offshore area was beyond the depth range (250m) of the Reson 8101 multibeam sonar.

Rugosity (surface area: planar area ratio) values for the Gull Island MPA and control sites range from 1-7.82 and 1-4.55, respectively. These results, particularly the maximum rugosity for the MPA, are higher than normally expected in a natural setting, and suggest problems with data quality. The highest rugosity values observed at Gull Island occur primarily along the sloping edges of the Santa Cruz Canyon, which cuts across the southwest third of the MPA. Along this slope, where the depths approach the depth limit of the 8101 sonar, the original sounding data obtained were of poor quality, resulting in a noisy, artifact-ridden bathymetric DEM (from which the rugosity was derived). Slope varies from 0° to 82° throughout the entire surveyed region with most of the values above 20° occurring along the canyon walls.

Abundance of rocky habitat within the Gull Island MPA (1.23 km$^2$, 4.7 %) is significantly different from that within the adjacent control site (0.18 km$^2$, 0.7%, two-sample t-test, $t = 2.47, n = 20, p < 0.05$) (Tables 3 and 4). When stratified by depth, the results are similar, with a significant difference between the abundance of rocky habitat inside (0.46 km$^2$, 7.5 %) vs. outside the Gull Island MPA (0.02 km$^2$, 0.2 %) in the 20-60 m depth range (two-sample t-test, $t = 2.25, n = 20, p < 0.05$).

CARRINGTON POINT MPA AND CONTROL

Approximately 84% (40.3 km$^2$) of the Carrington Point MPA was mapped, while 64.5% (21.8 km$^2$) of the adjacent control site was surveyed. The mapped area within the Carrington Point MPA extended from 6 – 88 m depth (MLLW). Portions of both the MPA and control sites could not be mapped due to the same physical barriers as reported at Gull Island above.

Rugosity values for MPA and control sites range from 1-1.85 and 1.1-1.74, respectively. These results are within the expected range of naturally occurring values for the geologic setting of the study site and resolution of the DEM analyzed, with maximum values typical of moderately rugose rocky reef habitat. The minimum rugosity value of 1 signifies that flat, smooth areas exist in the study site as well. Slope varies from 0° to 57° throughout the entire surveyed region with most of the visually identifiable rocky habitat having slopes between 5° and 11°.

Abundance of rocky habitat within the Carrington Point MPA (8.73 km$^2$, 21.6 %) does not differ significantly from that within the adjacent control site (4.19 km$^2$, 19.2%, two-
South Point MPA and Control

Approximately 72% (25.7 km²) of the South Point MPA was mapped, while 51% (12.4 km²) of the adjacent control site was surveyed. The mapped area within the South Point MPA extended from 7 – 253 m depth (MLLW). As with the other survey locations, portions of both the South Point MPA and control sites could not be mapped due to environmental factors. Although at South Point, the depth capability of the Reson 8101 multibeam sonar was a major factor in limiting the spatial coverage.

Rugosity in the South Point MPA ranges from 1(smooth) to 1.97 (moderately rugose), while in the adjacent control area the maximum rugosity is 2.11. Both the MPA and control site are predominantly smooth with moderately rugose rocky reef habitat dispersed throughout the 7-100 m depth range. Slope varies from 0° to 58° throughout the entire surveyed region with most of the visually identifiable rocky habitat having slopes between 5° and 58°.

Abundance of rocky habitat within the South Point MPA (1.12 km², 4.3 %) does not differ significantly from that within the adjacent control site (0.82 km², 6.6 %, two-sample t-test, t = 0.61, n = 17, p > 0.05) (Tables 3 and 4). No statistically significant difference was found between the abundance of rocky habitat inside (0.41 km², 7.5 %) vs. outside the South Point MPA (0.62 km², 13.3 %) in the 20-60 m depth range (two-sample t-test, t = 1.16, n = 7, p > 0.05).

Table 3. Amount of rocky habitat found within each of the MPAs and paired control sites.

<table>
<thead>
<tr>
<th>Rocky Habitat entire depth range</th>
<th>Area (km²)</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gull Island MPA</td>
<td>1.23</td>
<td>4.7%</td>
</tr>
<tr>
<td>Control</td>
<td>0.18</td>
<td>0.7%</td>
</tr>
<tr>
<td>t-test p value</td>
<td>&lt; 0.05</td>
<td></td>
</tr>
<tr>
<td>Carrington Point MPA</td>
<td>8.73</td>
<td>21.6%</td>
</tr>
<tr>
<td>Control</td>
<td>4.19</td>
<td>19.2%</td>
</tr>
<tr>
<td>t-test p value</td>
<td>&gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>South Point MPA</td>
<td>1.1</td>
<td>4.3%</td>
</tr>
<tr>
<td>Control</td>
<td>0.82</td>
<td>6.6%</td>
</tr>
<tr>
<td>t-test p value</td>
<td>&gt; 0.05</td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Gull Island habitat distribution by species of concern.

<table>
<thead>
<tr>
<th>Species of Concern</th>
<th>Common Depth Range</th>
<th>Preferred Habitat</th>
<th>MPA Available Habitat at Depth</th>
<th>Control Available Habitat at Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Area (km²)</td>
<td>% Rock Habitat</td>
</tr>
<tr>
<td>White Abalone (<em>Haliotis sorenseni</em>)</td>
<td>20 - 60 m</td>
<td>Rock</td>
<td>0.46</td>
<td>7.5</td>
</tr>
<tr>
<td>Olive Rockfish (<em>Sebastes serranoides</em>)</td>
<td>3 - 190 m</td>
<td>Rock</td>
<td>1.23</td>
<td>4.7</td>
</tr>
<tr>
<td>Lingcod (<em>Ophiodon elongatus</em>)</td>
<td>0 - 106 m</td>
<td>Rock</td>
<td>1.23</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Table 5. Carrington Point, Santa Rosa Island habitat distribution by species of concern.

<table>
<thead>
<tr>
<th>Species of Concern</th>
<th>Common Depth Range</th>
<th>Preferred Habitat</th>
<th>MPA Available Habitat at Depth</th>
<th>Control Available Habitat at Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Area (km²)</td>
<td>% Rock Habitat</td>
</tr>
<tr>
<td>White Abalone (<em>Haliotis sorenseni</em>)</td>
<td>20 - 60 m</td>
<td>Rock</td>
<td>6.87</td>
<td>30.6</td>
</tr>
<tr>
<td>Olive Rockfish (<em>Sebastes serranoides</em>)</td>
<td>3 - 190 m</td>
<td>Rock</td>
<td>8.73</td>
<td>21.6</td>
</tr>
<tr>
<td>Lingcod (<em>Ophiodon elongatus</em>)</td>
<td>0 - 106 m</td>
<td>Rock</td>
<td>8.73</td>
<td>21.6</td>
</tr>
</tbody>
</table>

Table 6. South Point, Santa Rosa Island habitat distribution by species of concern.

<table>
<thead>
<tr>
<th>Species of Concern</th>
<th>Common Depth Range</th>
<th>Preferred Habitat</th>
<th>MPA Available Habitat at Depth</th>
<th>Control Available Habitat at Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Area (km²)</td>
<td>% Rock Habitat</td>
</tr>
<tr>
<td>White Abalone (<em>Haliotis sorenseni</em>)</td>
<td>20 - 60 m</td>
<td>Rock</td>
<td>0.41</td>
<td>7.5</td>
</tr>
<tr>
<td>Olive Rockfish (<em>Sebastes serranoides</em>)</td>
<td>3 - 190 m</td>
<td>Rock</td>
<td>1.12</td>
<td>4.3</td>
</tr>
<tr>
<td>Lingcod (<em>Ophiodon elongatus</em>)</td>
<td>0 - 106 m</td>
<td>Rock</td>
<td>1.12</td>
<td>4.3</td>
</tr>
</tbody>
</table>
CONCLUSIONS

The habitat classification performed in this study using rugosity analysis was subject to many limitations imposed by data quality. Noise and artifacts in the bathymetric DEM severely limited the sensitivity and effectiveness of the algorithm used to identify rocky habitat. As a result, the criteria for classification as rocky habitat had to be made more stringent through the use of hand-drawn analysis masks and by raising threshold rugosity levels. Still, errors of both omission and commission were common, but an attempt was made to produce unbiased, conservative estimates of rocky habitat within the MPAs and their respective control sites, so that comparisons could be made between them.

Quantification and comparison of the distribution and abundance of rocky habitat within each MPA and their respective adjacent control sites indicate that both Santa Rosa Island MPA/control site pairs (Carrington Point and South Point) possess similar appropriate habitat for the three species-of-interest used in this study. Assessment of whether the amount of suitable habitat is adequate to produce the effects for which the MPAs were created (providing refuge, increased recruitment, higher diversity, etc.) is beyond the scope of this study, but the control sites appear to be appropriate for use in monitoring and evaluation of each MPA’s effectiveness. Although total area of the MPAs at Carrington Point (40.1 km$^2$) and South Point (25.4 km$^2$) are much larger than their control areas (27.9 km$^2$ and 12.4 km$^2$, respectively), the optimal habitat for species such as the white abalone (*Haliotis sorenseni*), olive rockfish (*Sebastes serranoides*), and lingcod (*Ophidon elongatus*) exists in both the MPAs and controls in similar proportions (Table 5 and 6).

The Gull Island control site does not however appear to be appropriate for use in monitoring and evaluating the effectiveness of the MPA, as the distribution and abundance of rocky habitat within the pair are significantly different from one another. Adjustment of the boundaries may be necessary if this MPA is to have an appropriate control site.

The analyses presented here are rudimentary and are offered as examples of methods for using geospatial tools and techniques for classification and quantification of habitats using remotely sensed acoustic data and imagery. The strategic design and supervision of Marine Protected Areas can be greatly aided by the implementation of geospatial analyses as a management tool. Habitat information provided by multibeam bathymetry and sonar-derived data may be used to validate placement of MPAs as well as design effective long-term monitoring programs of individual MPAs and entire MPA networks.
LITERATURE CITED


Jenness, Jeff. 2003. Surface Areas and Ratios from Elevation Grid v. 1.2


Lauck, T., Clark, C.W., Mangel, M., Munro, G.R. 1998. Implementing the precautionary principle in fisheries management through marine reserves. Ecological Applications. 8: S72-S78.


URL: http://arcscripts.esri.com


GIS DATA INDEX

DATASET OVERVIEW

GEOGRAPHIC EXTENT
Central California: Monterey Bay to Point Sur, includes survey sites of Monterey Peninsula, Yankee Pt., Soberanes Pt., Kasler’s Pt., and Hurricane Pt. along the Big Sur coastline. Data sets of South Monterey Bay Del Monte Shalebeds and squid project site included as appendices.

Southern California: Channel Island MPA areas, includes Gull Island off Santa Cruz Island, Carrington Pt. and South Pt. regions of Santa Rosa Island.

PROJECTION & COORDINATE SYSTEM
Thematic coverages are provided in Universal Transverse Mercator (UTM) projection, zone 10 & 11 North, WGS 1984 spheroid, units in meters. Data appended to these GIS projects by an ArcView® user must be in this same coordinate system for the added layers to display correctly. Layers added to ArcGIS® must have their coordinate system correctly defined to allow proper projection on-the-fly.

GENERAL DESCRIPTION OF DATA LAYERS
Data layers included in the ‘Hydrographic Data Acquisition’ GIS consist of raster, vector and tabular data sets from a variety of sources. Each of these layers is described in the table below followed by their placement within the data frames and views.

<table>
<thead>
<tr>
<th>Graphic example</th>
<th>Layer/Theme label</th>
<th>Source file</th>
<th>Description of content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Islands Coastline</td>
<td>ChannelIslandsCoast_UTM11.shp</td>
<td>Polyline shapefile of coastline derived from Teale Data Center California Coastline (ccoastn27.shp), warped to WGS1984 UTM Zone 11.</td>
<td></td>
</tr>
<tr>
<td>Channel Islands Coast Polygon</td>
<td>ChannelIslandsCoast_UTM11_poly.shp</td>
<td>Polygon shapefile of coastline derived from Teale Data Center California Coastline (ccoastn27.shp), warped to WGS1984 UTM Zone 11.</td>
<td></td>
</tr>
<tr>
<td>Bathymetric Contour Lines</td>
<td>cp_100bathy_10mcontour.shp GI_100bathy_10mcontour.shp sp_100bathy_10mcontour.shp</td>
<td>10-meter bathymetric contours derived from a 100-meter bathymetric grids</td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Data layers: example graphic, layer label as displayed, source file and description of content and source.
<table>
<thead>
<tr>
<th>Graphic example</th>
<th>Layer/Theme label</th>
<th>Source file</th>
<th>Description of content</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Navigation Charts" /></td>
<td>Navigation Charts</td>
<td>18720.tif</td>
<td>NOAA electronic raster charts.</td>
</tr>
<tr>
<td><img src="image" alt="Survey Footprint Polygons" /></td>
<td>Survey Footprint Polygons</td>
<td>cp_3mbathy_surveyfootprint.shp, GI_3mbathy_surveyfootprint.shp, sp_3mbathy_surveyfootprint.shp</td>
<td>Survey coverage (footprint) polygons from SFML 2003 multibeam surveys.</td>
</tr>
<tr>
<td><img src="image" alt="XYZ Soundings" /></td>
<td>XYZ Soundings</td>
<td>CPoint_100mxyz.shp, CPoint_300mxyz.shp, CPoint_500mxyz.shp, GI_100mxyz.shp, GI_300mxyz.shp, GI_500mxyz.shp, SP_100mxyz.shp, SP_300mxyz.shp, SP_500mxyz.shp</td>
<td>Shoal-biased soundings exported from Caris HIPS®. Soundings were exported in 100, 300, and 500-meter intervals.</td>
</tr>
<tr>
<td><img src="image" alt="Multibeam Geotiffs" /></td>
<td>Multibeam Geotiffs</td>
<td>cpoint_3mgs.tif, cpoint_3m_10clr.tif, gull_island_3m_gs.tif, gull_island_3m_10clr.tif, southpoint_3mgs.tif, SouthPoint_3m_10clr.tif, HurricanePoint_3m_gs.tif, HurricanePoint_3m_10clr.tif, kaslersPt_3mGS.tif, KaslersPt_3m10clr.tif, SoberanesPt_3mgs.tif, SoberanesPt_3mclr.tif, YankeePt_3mGS.tif, YankeePt_3m10clr.tif, MontereyBay_2m_gs.tif, MontereyBay_2m_10clr.tif, CyPt_Pn_2m_GS.tif, CyPt_Pn_2m_10clr.tif, Mstr_cyPt_2m_gs.tif, Mstr_cyPt_2m_10CLR.tif, PointLobos_3m_gs.tif, PointLobos_3m_10clr.tif, PtPn_CnRw_2m_GS.tif, PtPn_CnRw_2m_10CLR.tif, ShaleBeds_2m_gs.tif, ShaleBeds_2m_10clr.tif</td>
<td>Shaded-relief geotiff images for Channel Islands and Central Coast data exported from Caris HIPS®. Each geotiff was exported with a 1-3 meter resolution in grayscale &amp; 10 color format.</td>
</tr>
<tr>
<td><img src="image" alt="Sidescan Sonar Mosaic Geotiffs" /></td>
<td>Sidescan Sonar Mosaic Geotiffs</td>
<td>carringtonpoint_sss.tif, gull_island_sss.tif, SouthPoint_sss.tif, squidsss_100KHz_10cm.tif, squidsss_500KHz_10cm.tif, squidsss_500KHz_20cm.tif</td>
<td>50cm resolution sidescan sonar mosaic geotiffs for Channel Islands, Central Coast, and South Monterey Bay squid site data created using MicroImages TNT Mips® and Triton Elics International Isis and Delphmap software.</td>
</tr>
<tr>
<td>Graphic example</td>
<td>Layer/Theme label</td>
<td>Source file</td>
<td>Description of content</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------</td>
<td>-------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Bathymetric Grids</td>
<td>cp_3mbathy cp_100mbathy gi_3mbathy gi_100mbathy sp_3mbathy sp_100mbathy</td>
<td></td>
<td>3 and 100 meter resolution Arc Grid seafloor DEMs from multibeam bathymetry.</td>
</tr>
<tr>
<td>Slope Grids</td>
<td>cp_3mslope gi_3mslope sp_3mslope</td>
<td></td>
<td>3 meter resolution Arc Grids of slope of seafloor DEMs from multibeam bathymetry.</td>
</tr>
<tr>
<td>Hillshade Grids</td>
<td>cp_3mhill gi_3mhill sp_3mhill</td>
<td></td>
<td>3 meter resolution Arc Grids of hillshade of seafloor DEMs from multibeam bathymetry. Illumination azimuth 315°, Angle 45°.</td>
</tr>
<tr>
<td>Rugosity Grids</td>
<td>cp_3mrug gi_3mrug sp_3mrug</td>
<td></td>
<td>Rugosity analyses (surface area ratio) of seafloor DEMs from multibeam bathymetry. Generated using surfgrids.avx ArcView® 3.x® extension.</td>
</tr>
<tr>
<td>Buffer Points</td>
<td>CP_MPA_0-100m_buffer.shp CP_MPA_20-60m_buffer.shp CP_control_0-100m_buffer.shp CP_control_20-60m_buffer.shp GI_MPA_20-60m_buffer.shp GI_MPA_0-256m_buffer.shp GI_control_20-60m_buffer.shp GI_control_0-256m_buffer.shp SP_MPA_20-60m_buffer.shp SP_MPA_0-252m_buffer.shp SP_control_20-60m_buffer.shp SP_control_0-252m_buffer.shp</td>
<td></td>
<td>Random sampling locations generated within each MPA and control site to assess rocky habitat cover. Used ArcView® 3.x “Generate Randomly-Distributed Points” extension.</td>
</tr>
<tr>
<td>Rocky Habitat Analyses</td>
<td>cp_3m_rock gi_3m_rock sp_3m_rock</td>
<td></td>
<td>Identification of rocky habitat derived from rugosity analysis of the bathymetric DÉM.</td>
</tr>
</tbody>
</table>
GIS DATA & PROJECT ORGANIZATION

Data within site directories for the Channel Islands are organized as follows:

**Basemap**
- coastlines, NOAA chart BSB, and other reference layers

**Bathymetry**
- bathymetry products
  - ArcViewGrids - Bathymetry, Slope, & Hillshade grids
  - ContourLines - Shapefiles derived from bathy grid
  - Fledermaus - Fledermaus dtm/geo/shade, .sd, & .scene files
  - Footprint - Shapefile of survey footprint
  - GeoTiffs - GeoTiffs (10-color & grayscale relief) from CARIS
  - XYZ - xyz text & shapefiles

**Habitat**
- interpretive layers derived from bathymetry, sidescan, or others
  - ArcViewGrids - Rugosity, TPI, & other grids

**Sidescan**
- sidescan sonar mosaic GeoTiffs and other products.

**METADATA**

All data layers have complete, FGDC compliant metadata associated with the data files in ArcGIS® ArcCatalog®. Detailed metadata for data processing methods can be found in Data Quality--Process Step--Process Description. The Seafloor Mapping Lab used the ArcGIS® ArcCatalog® metadata system as an efficient way to document, review and manage the geodata holdings. ArcCatalog®’s metadata editor utilizes FGDC metadata content standards. Metadata in ArcCatalog® is stored in XML format, and consists of properties (geospatial footprint) and documentation (descriptive information). ArcCatalog® enables the user to associate a metadata record with the actual GIS data layer it describes allowing the user to extract and record metadata elements including bounding coordinates, point and vector object counts, native data environment and entity/attributes directly from the GIS data. Properties are automatically updated with current values via an internal synchrononization process, ensuring that the metadata is kept up to date with changes to the data source. Once created, FGDC-compliant metadata becomes part of the data file itself. It is automatically moved, copied, and deleted along with the associated data file. The ArcCatalog® metadata system can be customized - template creation, stylesheets, user defined fields, and data cataloging all serve to enhance the completeness and reliability of metadata creation and reporting.

**DATA ACCURACY**

The spatial accuracy of the data themes is variable and values are shown in the metadata files within the ArcGIS® project. With the exception of other sources (noted), the authors assume responsibility for the accuracy of the enclosed data.
APPENDIX - PREDICTING ROCKFISH DISTRIBUTIONS USING GIS AND MULTIBEAM BATHYMETRY DATA

A Capstone Project
Earth Systems Science Policy
California State University, Monterey Bay

by
Erica Summers-Morris

5 May 2004